



# Principles of Green Chemistry & Green Engineering

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## Approaches to Risk Reduction

$$\text{Risk} = f(\text{Consequence, Probability})$$

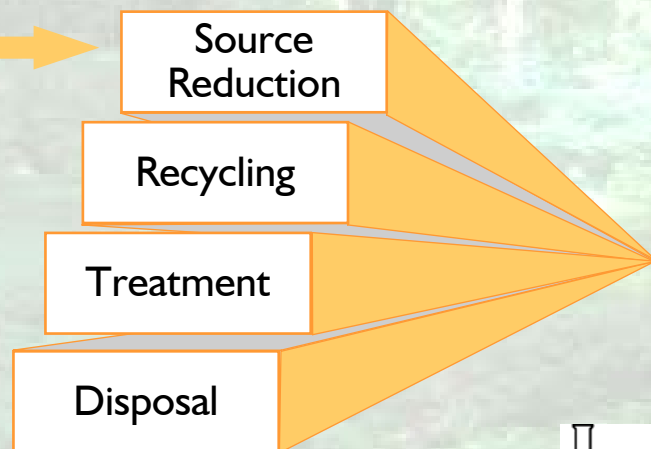
$$\text{Risk} = f(\text{Hazard, Exposure})$$





## Pollution Prevention Act: Risk Management Hierarchy

Pollution  
Prevention



## Green Chemistry – Definition

**Green chemistry** is the design of chemical products and processes to reduce or eliminate the use or generation of hazardous substances.





## Green Engineering – Definition

**Green Engineering** is the design, commercialization and use of processes and products that are feasible and economical while minimizing:

Risk to human health and the environment  
Generation of pollution at the source



## Principles of Green Chemistry

- Prevent waste
- Design safer chemical products
- Design less hazardous syntheses
- Use renewable feedstocks
- Use catalysts, not stoichiometric reagents
- Avoid chemical derivatization





## Principles of Green Chemistry

- Maximize atom economy
- Use safer solvents and reaction conditions
- Increase energy efficiency
- Design chemical products to degrade after use
- Analyze in real time to prevent pollution
- Minimize the potential for accidents



## Principles of Green Engineering

- Seek transformative technologies to achieve sustainability
- Engineer holistically
- Use life cycle thinking
- Conserve and improve natural ecosystems
- Minimize depletion of resources





## Principles of Green Engineering

- Design such that inputs and outputs are safe and benign
- Prevent waste
- Be sensitive to local geography, aspirations, and cultures
- Engage stakeholders



## Green Chemistry Includes

- |              |                       |
|--------------|-----------------------|
| • Feedstocks | • Synthesis           |
| • Reagents   | • Analysis            |
| • Catalysts  | • Monitoring          |
| • Solvents   | • Separations         |
| • Byproducts | • Reaction conditions |
| • Coproducts | • Formulations        |





## Green Engineering Includes

- Materials balance
- Energy balance
- Mass transfer
- Heat transfer
- Thermodynamics
- Reactor design
- Unit operations
- Chemistry
- Materials selection
- Cost
  - capital
  - operation
- Life cycle
- Siting



<http://www.epa.gov/oppt/greenengineering/>

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<http://www.epa.gov/greenchemistry>

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**Mission:** To promote innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products.

**Green Chemistry**

**This site offers:**

- [Basic Information](#) - History, Goals, and Partnerships
- [EPA Projects & Programs](#) - Presidential Green Chemistry Challenge Awards
- [Grants & Fellowships](#)
- [International Activities](#) - OECD Sustainable Chemistry Initiative
- [Tools & Literature](#) - Expert System, Searchable Database

**Highlights**

- **2007 Green Chemistry Challenge Winners**
- 1996-2007 Winners Brochure (PDF) (152 pp, 483 KB, Adobe PDF)
- Presidential Green Chemistry Challenge Status

**Green Chemistry Challenge**

- Program Information
- Winners by Year
- Winners by Topic
- How to Enter

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Last updated on Thursday, June 28th, 2007.  
<http://www.epa.gov/innovation/greenchemistry/index.html>

## Green Chemistry Program

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